CONTINUED SEARCH FOR RARE TYPES OF PRESOLAR SiC: GRAINS X AND Y. Sachiko Amari[1,2], Larry R. Nittler[1], Ernst Zinner[1], and Roy S. Lewis[2], [1]McDonnell Center for the Space Sciences and the Physics Department, Washington University, One Brookings Dr., St. Louis, MO 63130-4899, [2]Enrico Fermi Institute, University of Chicago, 5630 Ellis Ave., Chicago IL 60637-1433.

We have used high-mass-resolution isotopic imaging to locate rare types of presolar SiC among grains from the Murchison SiC fraction KJG (1-3 µm) [1]. This search, part of which has been reported previously [2], yielded 15 type X and 27 type Y grains. Two X grains have ^{41}K excesses due to the decay of ^{41}Ca with inferred ^{41}Ca/^{40}Ca ratios on the order of 10^{-3}. The isotopic features of Y grains indicate that they originated from highly evolved AGB stars. Multiple stellar sources with a range of metallicities are required to explain their Ti-isotopic ratios.

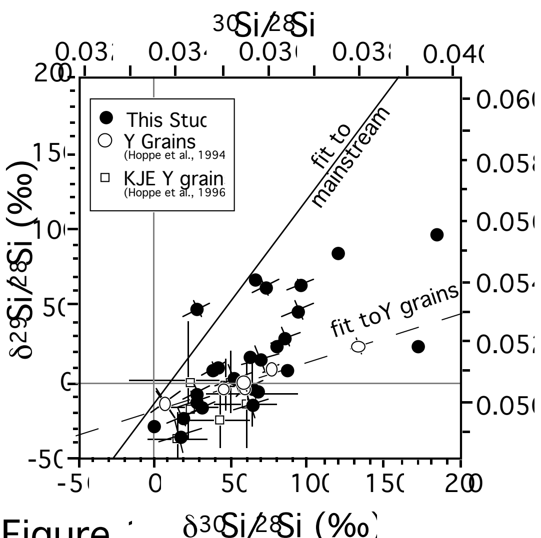
Type X grains are characterized by isotopically heavy N (^{14}N/^{15}N down to 13), high ^{26}Al/^{27}Al ratios (up to 0.6), ^{28}Si excesses (up to 5×solar) and are believed to have formed in ejecta from Type II supernovae [3-6]. Among the few grains for which we measured Ti-isotopic ratios, three have ^{49}Ti and/or ^{50}Ti excesses in the range of 300–400 ‰ (with errors of ~100‰). We analyzed K isotopes in 2 grains with relatively high Ca contents. Both grains have ^{41}K excesses (KJGM1-82-2: 1768±288‰ and KJGM1-341-3: 745±249‰). Since the highly volatile element K is not incorporated into the refractory SiC, the ^{41}K excess is most likely due to the decay of ^{41}Ca ($T_{1/2}=10^5$a). Inferred ^{41}Ca/^{40}Ca ratios in the two grains are $(5.8\pm0.7)\times10^{-3}$ (KJGM1-82-2) and $(1.8\pm0.5)\times10^{-3}$ (KJGM1-341-3), respectively. They fall in the range of ^{41}Ca/^{40}Ca ratios observed in low-density graphite grains [7], which are also considered to be of Type II SN origin. In supernovae, ^{41}Ca is produced either by neutron capture or by explosive nucleosynthesis, with expected ^{41}Ca/^{40}Ca ratios of 10^{-2} and $\leq10^{-3}$, respectively [8]. The other Ca-isotopic ratios measured in grain KJGM1-82-2 are normal within large errors, not allowing us to determine whether the ^{41}Ca was produced by neutron capture or explosive nucleosynthesis, as was possible for low-density graphite grains [7]. Interestingly, grain KJGM1-82-1 has nearly equal relative depletions in ^{29}Si and ^{30}Si (δ^{29}Si/^{28}Si = –428±3‰ and δ^{30}Si/^{28}Si=–456±4‰), suggesting deep mixing between the inner Si/S-rich SN zone (almost pure ^{28}Si) and the outer He-rich zones.

Type Y grains are characterized by high ^{12}C/^{13}C ratios (>140) and ^{30}Si enrichment relative to ^{29}Si [9, 10]. Silicon isotopic ratios of grains with ^{12}C/^{13}C> 100 are shown in Fig. 1. We chose this cutoff ratio, because one grain identified as type Y from its trace element abundance pattern has a ^{12}C/^{13}C ratio of 108 [11]. Almost all grains lie on the right side of the regression line for mainstream SiC. However, δ^{29}Si values vary much more than has previously been observed and the Si data do not fall on a single slope-0.35 line [9]. ^{14}N/^{15}N ratios range from 465 to 3470, similar to those of mainstream SiC grains. ^{26}Al/^{27}Al ratios are between 10^{-5} and 10^{-3}, falling into the previously observed range for type Y and mainstream SiC [9]. The fact that type Y grains have isotopic features similar to those of mainstream SiC [9] indicates that they formed in the same type of stars, that is, AGB (Asymptotic Giant Branch) stars, but higher ^{12}C/^{13}C ratios and δ^{30}Si values relative to δ^{29}Si suggest that Y grains formed in stellar envelopes with larger fractions of He-shell material, rich in ^{12}C, ^{29}Si and ^{30}Si, than mainstream SiC grains. It is likely that the AGB stars that produced Y grains either experienced a larger number of thermal pulses and dredge-ups or lost a large portion of the envelope before or during the third dredge-up.

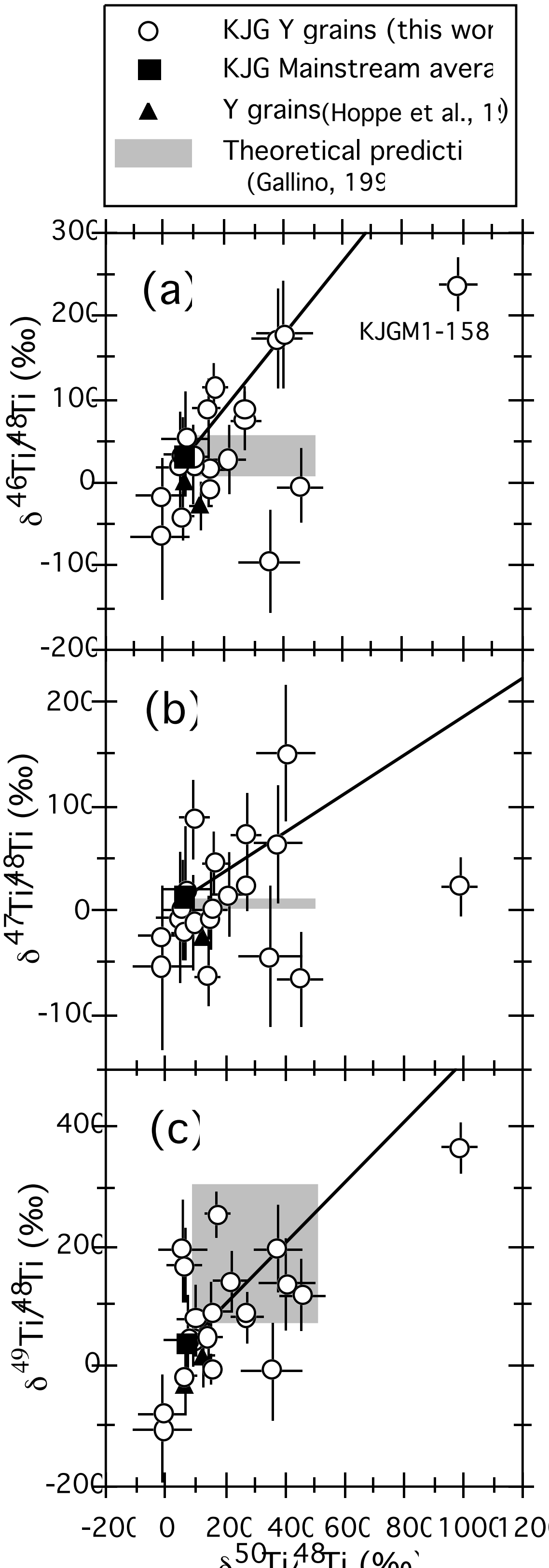
Fig. 2 shows the Ti-isotopic ratios measured for 20 Y grains. Also plotted are those measured in bulk (aggregates) SiC from the KJG fraction. Since Ti in bulk KJG samples was diluted by isotopically normal Ti from oxide grains, the true values for SiC should lie on the extrapolated mixing lines between the solar composition and the bulk measurement. Many Y grains lie close to the lines, being no different from mainstream SiC grains. However, a few grains lie to the right of the lines (Fig. 2(a) and (b)), indicating that these grains are more enriched in ^{50}Ti than mainstream SiC. Grain KJGM1-158-5 has the highest ^{50}Ti excess so far measured in SiC grains. δ^{46}Ti and δ^{47}Ti values range from -100 to 300‰ and from -100 to 200‰, respectively. δ^{46}Ti and δ^{47}Ti values in the He-shell are expected to vary only little with metallicity since the production of ^{46}Ti and ^{47}Ti is not very sensitive to neutron exposure (in theoretical models AGB stars with lower metallicity experience higher neutron exposure). On the other hand, as far as the Ti-isotopic compositions in the envelope of AGB stars reflect galactic chemical evolution, they depend on metallicity. It is estimated that He-shell material is diluted in the envelope by a factor of 50 to 100. The shadowed regions in Fig. 2 indicate ranges of theoretically expected Ti-isotopic ratios in the envelope of AGB stars of 1.5 and 3 $M_{\odot}$ stars of solar metallicity with C/O > 1 [12]. Since the measured ratios considerably exceed these ranges we cannot explain the Ti-isotopic compositions of Y grains by the evolution of the envelope of a single AGB star during its whole thermal-pulse history. We therefore conclude that Y grains come from different stars with a range of metallicities. Such a conclusion has previously been reached for mainstream SiC grains on the basis of their Si- and Ti-isotopic compositions [13-16].

ACKNOWLEDGMENTS: We thank Roberto Gallino for stimulating discussions on type Y grains and for providing unpublished results of theoretical calculations.

REFERENCES: [1] Amari S. *et al.* (1994) *GCA* **58**, 459. [2] Amari S. *et al.* (1996) *Met. & Planet. Sci.*, **31**, A6. [3] Amari S. *et al.* (1992) *Ap J.*, **394**, L43. [4] Nittler L. R. *et al.* (1995) *Ap. J.*, **453**, L25. [5] Nittler L. R. *et al.* (1996) *Ap. J. Lett.*, **462**, L31. [6] Hoppe P. *et al.* (1996) *Science,* **272**, 1314. [7] Amari S. *et al.* (1996) *Ap. J.*, **470**, L101. [8] Woosley S. E. and Weaver T. A. (1995) *Ap. J. Suppl.*, **101**, 181. [9] Hoppe P. *et al.* (1994) *Ap. J.*, **430**, 870. [10] Hoppe P. *et al.* (1996) *GCA,* **60**, 883. [11] Amari S. *et al.* (1995) *Meteoritics,* **30**, 679. [12] Gallino R. (1996) pers. comm. [13] Alexander C. M., O'D. (1993) *GCA* **57**, 2869. [14] Gallino R. *et al.* (1994) *Ap J.*, **430**, 858. [15] Timmes F. X. and Clayton D. D. (1996) *Ap. J.*, in press. [16] Clayton D. D. and Timmes F. X. (1996) *Ap. J.*, submitted.



Figure



Figure